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MODELLING OF GROWTH STRESS GENERATION AND TIMBER DISTORTIONS RELATED TO LOG SAWING AND FORCED DRYING

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ABSTRACT

Growth stresses can cause fibre collapse in living trees (often in combination with strong wind loading), internal checking resulting in end-splitting of logs, and instantaneous board distortions when the log is split into timber. How much the growth rate and growth stresses affect the final shape stability of solid timber products is not fully understood. For trees with abnormal growth conditions resulting in eccentric growth and generation of reaction wood, it is very complicated to estimate how timber products made of such material will behave during moisture variation. To study this behaviour a finite element analysis in which stress formation during normal and abnormal tree growth was simulated with the aim of better understanding of the growth stress formation.

The model for progressive growth stress generation in trees with normal growth conditions is formulated as a one dimensional axisymmetric general plane strain model of the tree stem. The trunk is considered as a very long solid cone with zero shear stresses. In the model, each new (and stress free) annual ring is progressively added to the stem during the analysis. Thereafter the cell maturation is assumed to start, i.e. the crystallization of the cellulose leads to longitudinal shrinkage of the new annual ring whereas the lignification process results in transversal expansion of the fibres. Since the maturing annual ring is attached to the old and already matured rings, a strain constraint develops in the stem. The new annual ring becomes stretched longitudinally and compressed tangentially, whereas the matured rings are exposed to the opposite stress conditions. The material model used is based on the assumption of small strains and the biological maturation strains are used as a driving force for the growth stress evolutions. The aim here is also to take into account viscous effects of the wood material.

The model for growth stress generation in trees with abnormal growth conditions is based on formulation of two-dimensional general plane strain assumptions where a constant curvature of the stem is taken into account as well. The wood material properties can vary arbitrary over the cross section and the new annual ring can get eccentric growth based on the stress state in the already matured annual rings. In highly loaded parts of the trunk where the tree starts to generate compression wood all material properties need to be updated for representing compression wood. The element type developed here is a six-node isoparametric element in the cross-section plane (linear and

quadric in the radial respective the tangential direction) with two additional degrees of freedom for simulating deformation in the stem direction. The theory was implemented into the FE-toolbox CALFEM [1] by writing special sub-routines for material behaviour, material orientation, boundary conditions, element properties and stresses. All material properties and micro-fibril angles are created on the basis of information concerning a growth index and an annual ring number described in Ormarsson et al. [4].

These models have been used to study how growth stresses are influenced by different wood properties and growth conditions. A three-dimensional finite element board distortion model developed by Ormarsson [3] has been extended to be able to simulate distortions related to the redistribution of growth stresses during log sawing and distortions and stresses in drying reflecting the effects of growth stresses. The final stress state from the growth stress model was used as an initial stress field for the log model. This was implemented into ABAQUS [2] through a specifically written subroutine for initial stresses. The logs were sawn into several boards by progressively removing thin layers of elements that represent the path of the saw blade. This results in distortions of the new sawed timber boards when they seek a new equilibrium state. Figure 1*(a)* shows how longitudinal growth stresses vary along the radial path during 120 years growth of a tree with good growth conditions and Figure 1*(b)* and 1*(c)* show distortions of board A after sawing and drying respectively.

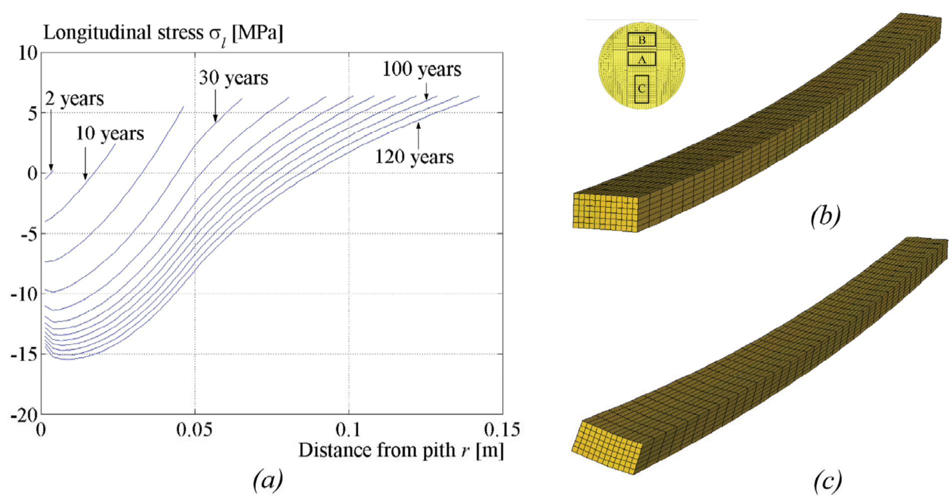

Figure 1: Growth stresses and distortion of board A (def. are magnified by factor of 3), *(a)* longitudinal stress profiles during 120 years for a tree with good growth condition *(b)* distortion after sawing (bow), *(c)* distortion after drying (both twist and bow).

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